INTEGRATED ITM MICROMIXER BURNER OF SHELL AND TUBE DESIGN FOR CLEAN COMBUSTION IN GAS TURBINES

BACKGROUND

Technical Field

[0001] The present disclosure is directed to a system and methods for using an integrated ion transport membrane (ITM) micromixer burner of shell and tube design for clean combustion in gas turbines.

Description of Related Art

[0002] The "background" description provided herein is for the purpose of generally presenting the context of the disclosure. Work of the presently named inventors, to the extent it is described in this background section, as well as aspects of the description which may not otherwise qualify as prior art at the time of filing, are neither expressly or impliedly admitted as prior art against the present invention.

[0003] The tremendous increase in energy demand due to increased population and rapid economics has resulted in increased levels of atmospheric pollutants and global warming. The global shift to the use of renewable clean energies still has some restrictions in terms of the availability of advanced reliable technologies and the cost of application compared to conventional fossil fuels. As full conversion to renewable energy proceeds slowly, the development of advanced techniques for clean combustion of fossil fuels is needed to curb global warming. Forced by the simultaneous increased pressure of strict emissions regulations and the target of limiting global warming to 2° C., gas turbine manufacturers have developed new combustion techniques for clean power production in gas turbines. These new techniques depend either on modification of existing combustion systems or the development of novel burners for clean power production. One of these techniques is to control engine emissions while generating stable flame by using a micromixer stabilized burner.

[0004] A micromixer is based on the principle of mixing fuel and an oxidizer on a miniature scale. Multiple straight tubes of millimeter-scale diameter are arranged in a parallel array between front and back faceplates, which form a cavity surrounding the tubes between the faceplates. The incoming oxidizer flow is divided among those tubes, and fuel is injected from the surrounding cavity through numerous sub-millimeter-scale side holes in the tube walls. Thus, fuel is injected in a jet-in-crossflow fashion into the oxidizer stream. The axial location of fuel holes is chosen to create a premixing region inside each tube, which guarantees a fully developed, fully premixed jet exiting the tube. To minimize the premixing length, two or more fuel holes are evenly spaced around the perimeter of each tube at the same axial location. Flow conditioners are utilized within the fuel tubes to ensure uniform distribution of fuel among all injection holes. From a combustion perspective, the faceplate geometry (jet spacing and diameter and number of jets) is tailored to optimize emissions and control combustor operability. The pressure drop of oxidizer flow across micromixer and the operational equivalence ratio are both chosen carefully to prevent flame flashback.

[0005] One of the key aspects behind the success of micromixer technology is its innate flexibility to accommodate staging, scalability, and fuel dilution and flexibility. York et al. performed a full-can durability test of micromixer nozzles at the combustor-inlet and firing conditions of General Electric's F-class gas-turbine conditions at full engine load with air as oxidizer and different fuel blends of hydrogen, natural gas, and nitrogen. During 100 hours of accumulated firing, NOx emissions were recorded at single-digit ppm levels using a blend of hydrogen and nitrogen as fuel with more than 90% hydrogen by volume. (See York W. D., Ziminsky W. S., and Yilmaz E., "Development and Testing of a Low NOx Hydrogen Combustion System for Heavy-Duty Gas Turbines", Eng. Gas Turbines Power, 2013; 135,022001, incorporated herein by reference in its entirety).

[0006] Funke et al. conducted an experimental/numerical study of the impact of momentum-flux ratio on flame anchoring and NOx-emissions in micromixer nozzles using hydrogen as fuel and air as oxidizer. (See Funke H. H. W., Boerner S., Keinz J., Kusterer K., Kroniger D., Kitajima J., Kazari M., and Horikawa A., "Numerical and Experimental Characterization of Low NOx Micromix Combustion Principle for Industrial Hydrogen Gas Turbine Applications", Proc. ASME Turbo Expo, 2012; 2,1069-1079, incorporated herein by reference in its entirety).

[0007] Dodo et al. tested micromixer air-combustion of IGCC-syngas fuel simulants containing hydrogen, methane, and nitrogen with a hydrogen content of 40-65%. Three fuel blends were considered with 0, 30, and 50% carbon-capture rate. Stable combustion was observed for all blends with single-digit ppm NOx. (See Dodo S., Asai T., Koizumi H., Takahashi H., Yoshida S., and Inoue H., "Combustion characteristics of a multiple-injection combustor for dry low-NOx combustion of hydrogen-rich fuels under medium pressure", Proc. ASME Turbo Expo, 2011; 2,467-476, incorporated herein by reference in its entirety).

[0008] When nitrogen is released during fuel combustion it combines with oxygen atoms to create nitric oxide (NO). This further combines with oxygen to create nitrogen dioxide (NO_2). Nitric oxide is not considered to be hazardous to health at typical ambient concentrations, but nitrogen dioxide can be. Nitrogen dioxide and nitric oxide are referred to together as oxides of nitrogen (NOx).

[0009] NOx gases react to form smog and acid rain as well as being central to the formation of fine particles (PM) and ground level ozone, both of which are associated with adverse health effects.

[0010] NOx is produced from the reaction of nitrogen and oxygen gases in the air during combustion, especially at high temperatures. In areas of high motor vehicle traffic, such as in large cities, the amount of nitrogen oxides emitted into the atmosphere as air pollution can be significant. NOx gases are formed whenever combustion occurs in the presence of nitrogen—e.g. in car engines; they are also produced naturally by lightning.

[0011] NOx mainly impacts respiratory conditions by causing inflammation of the airways at high levels. Long term exposure can decrease lung function, increase the risk of respiratory conditions and increases the response to allergens. NOx also contributes to the formation of fine particles (PM) and ground level ozone, both of which are associated with adverse health effects.

[0012] Additionally, high levels of NOx can have a negative effect on vegetation, including leaf damage and reduced growth. It can make vegetation more susceptible to disease